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T. Mahmood, M. Zawadzki, and S. Banerjee

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# Pilot Study of Impulse Drying Industrial Sludge

Talat Mahmood, Michael Zawadzki, Sujit Banerjee

Institute of Paper Science and Technology
500 10th Street N.W.
Atlanta, GA 30318

## Abstract

In impulse drying, a moving sheet of pressed sludge contacts a hot roll under pressure, thereby converting water at the sludge-roll interface to steam. The resulting pressure expresses a part of the water from the sludge in liquid form. Belt-pressed primary sludge from two paper mills was impulse-dried on a pilot scale. In one case, solids increased from 33 to 56%; in the other an improvement from 32 to 46% was realized. Roll sticking or blinding of the belt did not occur at roll temperatures exceeding 200°C. Energy costs are projected at about 60 KWH per ton of dry solids. The technology provides an inexpensive energy-efficient means of increasing sludge solids.

## Introduction

Impulse drying was initially developed for dewatering a wet web of paper (1,2). A hot roll contacts the web, flashing the moisture at the roll-web interface to steam. The resulting pressure then forces out some of the water in the web in liquid form, thereby conserving the heat of evaporation. The application is quite complex for paper, since heat transfer to the web must be tightly controlled in order to prevent sheet delamination (3,4). These difficulties are absent for sludge, where the properties of the dewatered product are relatively unimportant. Laboratory-scale work has shown that impulse drying belt-pressed industrial, municipal, and a mixture of municipal and industrial sludges removes up to an additional 20 percentage points of water (5-7), most of it as liquid. Here, a hot platen briefly impacts a layer of sludge resting on a blotter, and the weight gained by the blotter is taken as a measure of the water lost from the sludge in liquid form.

These laboratory measurements represent a batch process, and extension of the impulse concept to a continuous operation must address several additional uncertainties. For example, it is well known that there is a practical limit to the solids gain achievable by pressure alone (8,9). Also, belts or screens used to support the sludge frequently blind under pressure (10). Potential sticking of the sludge to the hot surface is yet another issue. In this paper we demonstrate a pilot application of impulse dewatering of a primary paper mill sludge, conveyed by a metal belt through a heated nip.

## Experimental

Primary sludge was obtained from two paper mills: Riverwood International's Macon, GA, mill, and the Hawkinsville, GA, facility of Hollingsworth and Vose (H&V). Riverwood makes coated board, and the sludge consisted of fiber and inorganic fillers such as clay. H&V is a small specialty mill whose products include filter paper. Sludge was collected in the form of intact sheets as it emerged from the belt-press, placed on 1 x 4 foot melamine-coated boards, and wrapped in plastic to prevent moisture loss. The sheets were stored separately to prevent compression, and were used within 48 hours of collection. The properties of the sludges are provided in Table 1. Pilot work was done on the custom-built unit illustrated in Figure 1. Heat is supplied through an inductively heated top roll. The lower roll is grooved to remove the expressed water, and to minimize rewet.

The unit was originally designed to operate at speeds over 2,500 fpm for dewatering paper. A 10:1 gear reduction allowed operation in the 5-20 fpm range. The individual rolls were driven from line-shaft clutch/brake systems for independent control. By design, variation in roll surface speed due to thermal expansion was compensated for by slippage in the upper roll clutch (rated at 50 foot-pounds torque) as the nip was closed. Clutch slippage was detrimental for our application since it limited the maximum applicable nip pressure, and the clutch was removed. The upper roll was driven directly from the lower roll, which was linked to a pneumatic clutch. However, even with these modifications, the Riverwood sludge could only be processed at a peak pressure of 324 psi, beyond which the torque was insufficient to drive the web through the nip.

The peak nip pressure in the pilot impulse dryer was determined by a TekScan 5501 pinch roll sensor. The fabric usually used for paper applications was replaced by a belt supplied by National Filtration (style 23 x 110 CD, 510 scfm airflow). The belt run was 26 feet, and had a width of 18 inches. Its tension was maintained at 50 psi. Sludge sheets were placed on a wooden platform at the height of the belt, and were gently pushed onto the moving belt. The nip was closed just after the leading edge of the sheet entered the nip. An early concern was that the sheet would not have the strength to pass through the nip at high pressure, but would bunch up at the front end of the roll. This is not an issue with paper, since the caliper is a maximum of about 600 microns, and the wet web has considerable machine-directional strength. On the other hand, the sludge sheet was much thicker, and was of much lower strength due to the absence of a web structure. However, the sludge was strong enough to cleanly pass through the nip under all the conditions used.

Laboratory measurements were conducted on a Materials and Testing Systems electrohydraulic press, illustrated in Figure 2. The heated upper platen impacts the sludge, which rests on a blotter, which absorbs the expressed water. A haversine pressure pulse is applied to simulate the pressure profile of the pilot machine.

## Results and Discussion

Results from the pilot trial for the H&V sludge are illustrated in Figure 3. A control measurement run at room temperature (26°C) to isolate the effect of pressure alone, showed an initial gain of about 10 percentage points. However, the belt was blinded through severe sludge extrusion, which was then very difficult to clean. Hence, essentially no solids gain would be realized when the belt returned to contact fresh sludge. It is well-known that pressure, alone, leads to minimal additional dewatering. For example, Tiller et al. (8) note that flow through compressible cakes forms a tight skin of low porosity adjacent to the supporting medium. Sorensen and Hansen (9) similarly observe that filtrate flow becomes independent of the applied pressure for compressible solids. The extrusion problem disappeared at 153°C, although now, a small amount of sludge stuck to the hot roll. Dewatering was much more facile at 200°C, where both roll sticking and extrusion were minimal. Figure 3 demonstrates that solids increase with increasing pressure and temperature. For the best case, an additional 23 percentage points of water were removed, giving a final solids of 56% at a peak pressure of about 819 psi, [10 fpm=1 sec dwell]. Higher pressures appear to lead to poorer results, probably because of sludge consolidation. In earlier laboratory work (5), we noted that the bulk of the water lost was removed as liquid, rather than as steam. This was qualitatively confirmed in the pilot study. A videotape revealed that while a light mist of steam developed at the roll-sheet interface, it was minimal compared to the liquid water lost at the lower roll. We estimate that evaporation accounted for less than 5% of the total water removed.

The same batch of H&V sludge used in the pilot trial was processed in the laboratory electrohydraulic press, and the results are included in Figure 4. The pilot results are much better at both room temperature and at 200°C, and are more sensitive to pressure than are the laboratory data. The most likely rationale is that the laboratory press can only dewater in the *z* direction, whereas *xy* dewatering can also occur in the nip of the pilot unit. Differences in rewet may be an additional factor.

At 10 fpm, the pilot dryer processed about 0.8 tons of sludge per hour. Energy use was approximately 15 kWH, which translates to about 60 kWH per dry ton. A similar value can also be estimated from theory. Heat is principally utilized to evaporate the small amount of water lost as steam. Other losses occur through heating the sludge and the expressed water, heat transferred to the belt, and radiative loss from the roll. The heat requirement was estimated for the following typical conditions: top roll: 200°C; bottom roll: 30°C; ingoing sludge: 30% solids; outgoing sludge: 45% solids; speed: 10 ft/min.; sheet thickness: 0.5 inches; sludge density: 2.7 lb/ft$^2$; loss as steam: 5%; outgoing sludge temperature: 45°C. Under these conditions, the amount of sludge processed is 486 lbs/hr of dry solids, and the total water removed is 530 lbs/hr.

The radiative heat lost from the hot roll is given by

$$q_{rad} = \varepsilon \sigma A \left( T^4 - T^4_{ambient} \right)$$

where T is the roll temperature in °K; ε, the emissivity, equals 0.2, σ, the Stefan-Boltzmann constant, is $5.669 \times 10^{-8}$ W/m$^2$ °K$^4$; and A is 2.336 m$^2$, from which $q_{rad}$ = 1,102 W = $4 \times 10^6$ J/hr (11). The heat required to warm the expressed water to 45°C is $14 \times 10^6$ J/hr, and is 22x$10^6$ J/hr for heating the outgoing water and sludge. The heat lost through steam is $28 \times 10^6$ J/hr. We assumed that the dry primary sludge is mainly comprised of wood fiber whose specific heat was taken to be that of paper, i.e., 1.34H/g°K (11). Finally, the heat required to heat the stainless steel belt (160 kg/hr) is $1 \times 10^6$ J/hr, assuming a heat capacity of 480 J/kg.°K. The total heat requirement is, therefore, $6.9 \times 10^7$ J/hr or 76 kWH per dry ton. Despite the many assumptions, the correspondence between theory and experiment is acceptable, demonstrating that the energy costs, while significant, are minor compared to present and projected disposal costs.

The Riverwood sludge was more compressible than the H&V material, and the sheet would not traverse the nip at pressures exceeding 324 psi. The high compressibility of the Riverwood sludge resulted in a relatively larger nip width, which increased the dwell. The results illustrated in Figure 5 for a trial at 5 fpm (3-second dwell) show a gain of about 7 percentage points over room temperature pressing. However, the room temperature data are misleading, since the belt rapidly blinded as with the H&V sludge, and the 7 percentage point gain achieved could not have been sustained. No blinding, whatsoever, occurred at 300°C under impulse conditions. Importantly, the solids gain is consistent with laboratory results with the electrohydraulic press on Riverwood sludge sampled earlier, where a 9 percentage point gain was realized at 500 psi pressure, 350°C temperature, and 0.7-second dwell (5). Since 24 percentage points were obtained at 1,200 psi in the laboratory study, an equivalent performance can be anticipated from a higher torque machine, particularly in view of our experience with the Hollingsworth and Vose sludge, where the pilot scale performance exceeded that of the laboratory press.

In summary, impulse drying overcomes the traditional limitation of high pressure dewatering, namely skin formation and sludge extrusion into the belt, and is able to appreciably increase sludge solids. The energy costs for heating the roll are significant, but small in comparison to the amount of water removed. Since the pilot results were superior to the laboratory-derived values, the performance realized with secondary sludge in earlier laboratory work (5) should be at least matched, if not exceeded, on a pilot scale. Commercialization of the technology is being collaboratively pursued with Ashbrook Corporation, Houston, TX. The 10-fpm rate used for the pilot approximates that of a typical belt press, and retrofits of existing presses should be feasible. Also, since the impulse unit has a small footprint, installation costs should be relatively low.

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| **Table 1: Properties of the sludges used** | | | |
|---|---|---|---|
| **sludge** | **percent solids** | **percent ash** | **percent acid insoluble ash** |
| Riverwood | 32 ± 2 | 44.6 ± 0.5 | 15.7 ± 0.2 |
| H&V | 33 ± 1 | 4.2 ± 0.1 | 2.69 ± 0.02 |

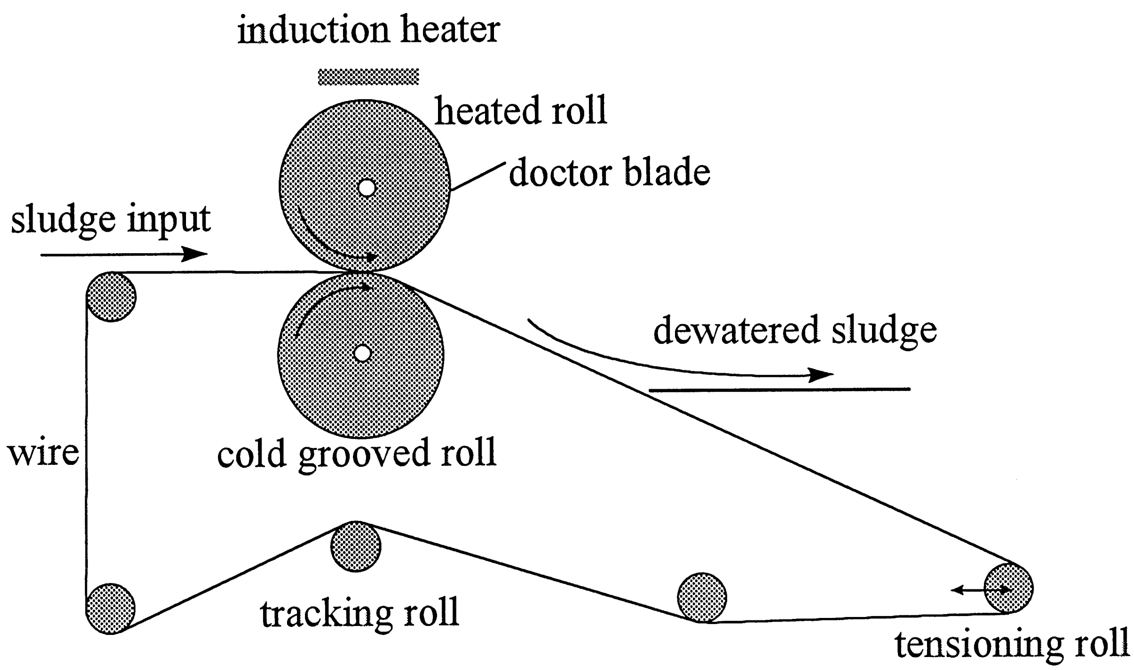


**Figure 1**: Side view schematic diagram of the pilot-scale sludge impulse dewatering press.

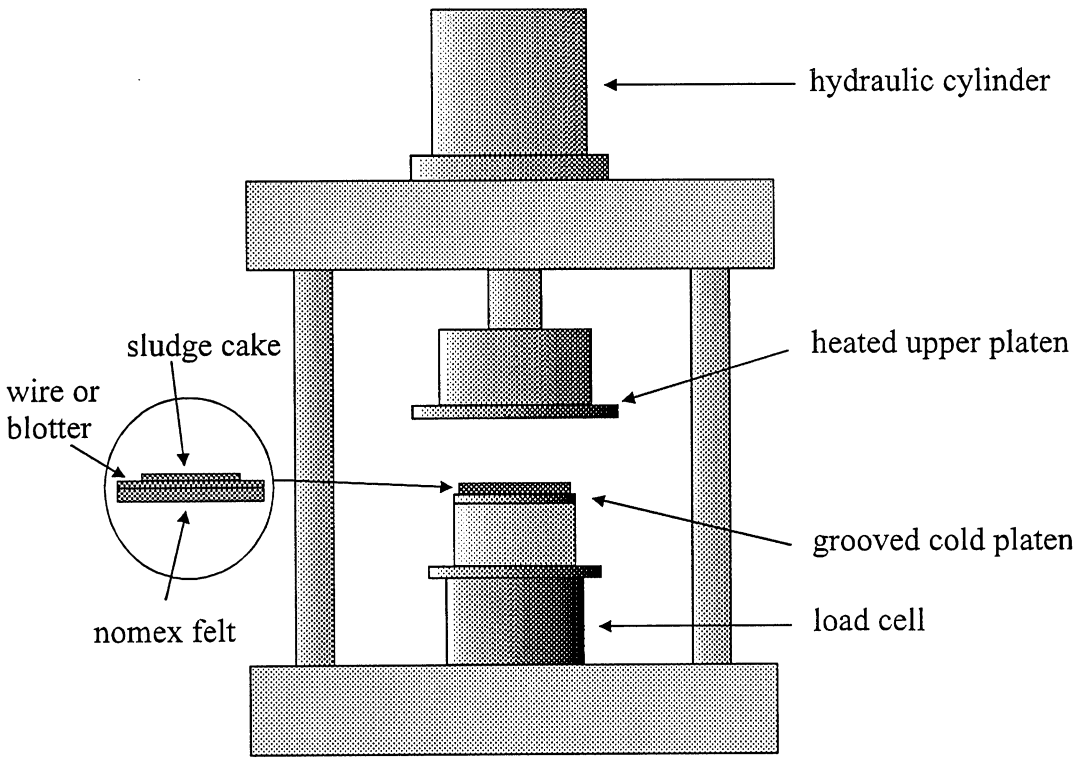


**Figure 2**: Schematic diagram of the MTS electrohydraulic press.

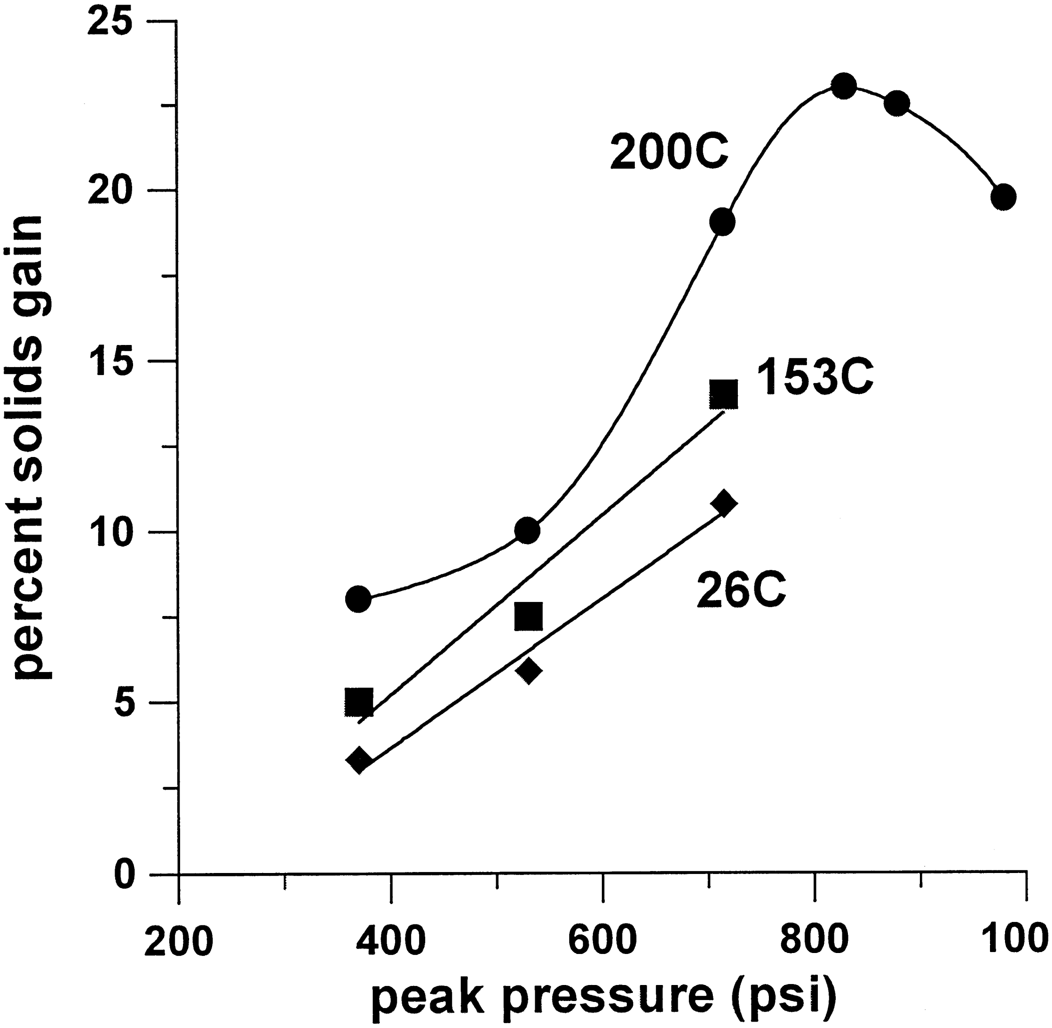


**Figure 3**: Pilot impulse drying of Hollingsworth and Vose sludge.

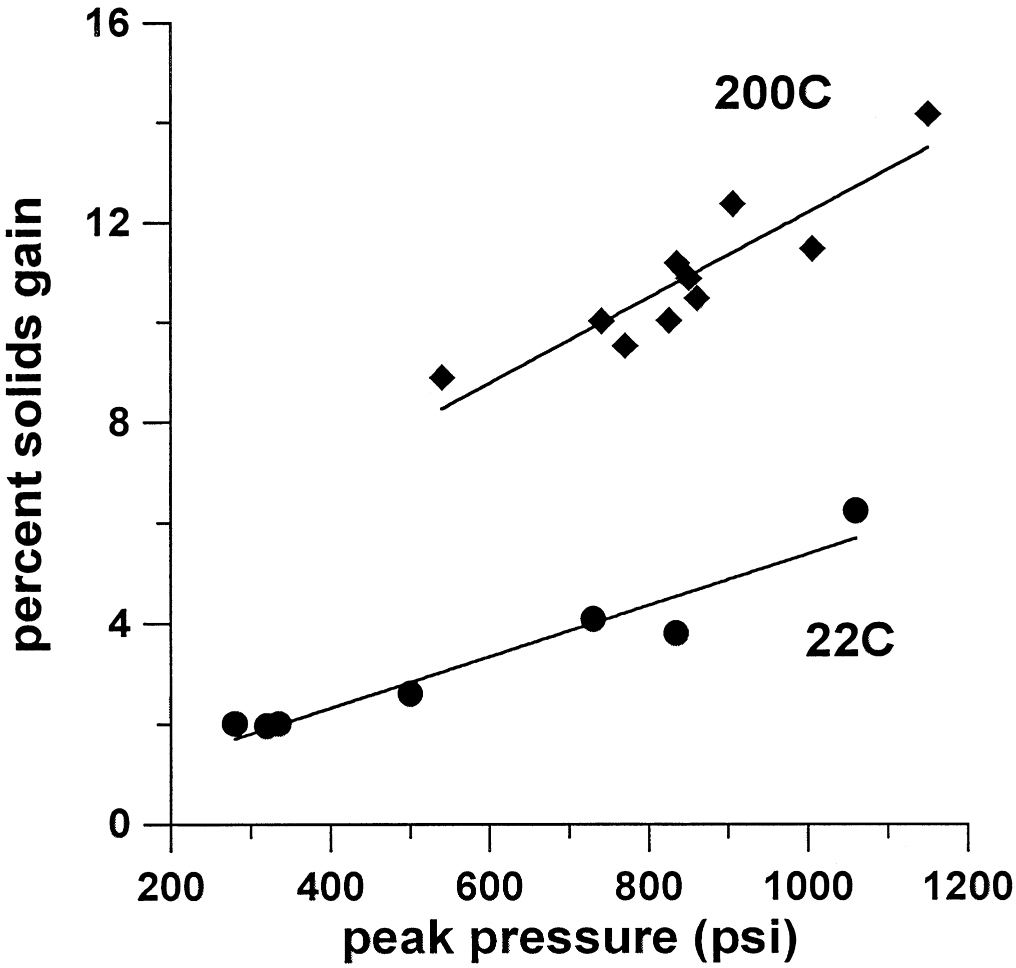


**Figure 4:** Impulse drying of H&V sludge using electrohydraulic press.

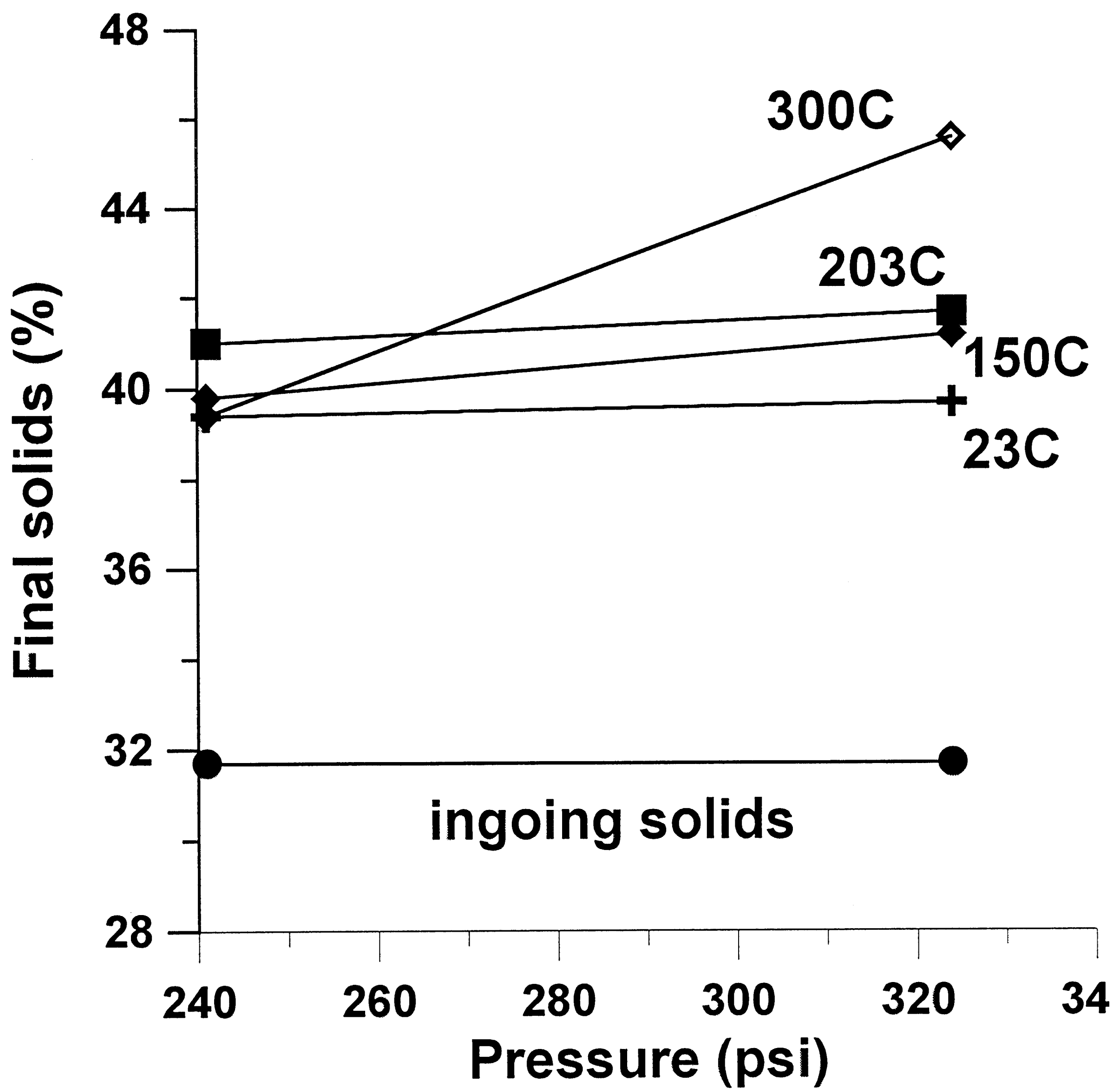


**Figure 5**: Pilot impulse drying of Riverwood sludge.